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RECENT PROGRESS AND TENDENCIES IN MUNICIPAL WATER SUPPLY IN THE UNITED STATES¹

BY JOHN W. ALVORD

It is often worth while to turn from the immediate and exacting problems that absorb our attention from day to day and pause to survey our accomplishments and review briefly the progress we have made. Particularly is it a pleasure to summarize progress in the important field of municipal water supply engineering, where the advancement of the art has been most gratifying in recent years and where new prospects have been opened up for further improvement and service to the public.

About one hundred years have elapsed since the pioneer water-works plants in this country were first put in operation. The intervening century has witnessed a very remarkable concentration of urban population, which has greatly stimulated and been in large measure conditioned upon the extensive growth of our now great municipal water supply systems, and with the spread of modern habits of life and enterprise a multitude of smaller water works plants have sprung up all over the country, until all but the very smallest communities now enjoy the benefits of a public water supply.

These conditions have created a large field for the development and exploitation of methods and equipment for water supply, but have not as yet resulted in any considerable degree of standardization of water works practice. Evolution of our water-works systems and of water works practice is still in progress. A great deal has been accomplished, especially in the last ten or fifteen years, to make our public water supplies all that they should be, but much still remains to be done. The progress of the past few years has been mainly in the direction of the development of new supplies on unprecedented scale, radical new methods of water purification, new developments in pumping machinery and measures to reduce water waste. It is the purpose of this paper to briefly review this recent progress and to point out present tendencies.

¹ Read before the Richmond convention, May 8, 1917.

DEVELOPMENT OF WATER SUPPLY SOURCES

With continued growth all of our larger cities have found it necessary in recent years repeatedly to make large additions to their water supplies.

The cities most favorably situated to keep pace with the endless demand for water in increasing quantity are those bordering on the Great Lakes and on our larger rivers, where it has only been necessary to increase the pumping capacity to get more water. But the quality of the water has complicated this otherwise simple problem, and even our lake cities have found increasing embarrassment in this direction. In the attempt to eliminate turbidity and secure more uniformly potable and safe water, the larger cities have extended their intakes further from the shores and to greater depth of water. In the past few years Cleveland, Chicago and Milwaukee have all sought this costly solution of their water problem, with *indifferent* success. Cleveland has finally adopted filtration, Chicago sterilizes its water and Milwaukee must come to filtration if it is to have a safe and satisfactory water. With the increasing pollution of the lakes, and the growing demand for pure, clear water at all times, the tendency of thought is towards the filtration of lake supplies. Many of the smaller cities, including Sandusky and Lorain, Ohio, Erie, Pa., and more recently Niagara Falls, N. Y.; Evanston, Ill.; South Milwaukee, Wis.; Bay City, Mich.; East Chicago, Ind., and others have adopted filtration.

The water supply problem of our large river cities has continued to be a comparatively simple one in point of quantity but has presented increasing difficulties, mainly by reason of the very general and rapidly increasing pollution of most of our streams. In the face of these difficulties, the past twenty years and particularly the decade just past have witnessed an immense improvement in quality of the more important river city supplies, following the introduction of filtration. Since the pioneer application of filtration on a large scale at Louisville, important river cities, including New Orleans, St. Louis, Kansas City, Minneapolis, Evansville, Pittsburgh, Philadelphia and Washington, and many smaller cities, have introduced filtration of their water supplies within the past few years.

It is among impounded and gravity supplies that we find the most notable water supply developments recently constructed or under

way. These include the great new gravity supplies for New York, Los Angeles and San Francisco. The great dams and aqueducts of the Catskill supply for New York, at an estimated cost of about \$200,000,000, will provide an additional 200,000,000 gallons per day of unpolluted mountain water and will be capable of future enlargement to yield twice this amount. This great undertaking, only just completed, had its inception as early as 1900. After exhaustive investigation actual construction was undertaken in 1906. While this addition to the New York water supply was under way, the city in 1911 faced a serious drouth and threatened water famine. This incident illustrates the necessity for foresight and wise planning if the water-works of our great cities are to be kept in point of development where they can safely meet the rapidly increasing demand for water, having due regard to natural causes affecting the quantity of the available supply from year to year.

Of no less interest is the recently completed Owens River supply developed by the city of Los Angeles. Rather than limit the future of the city by attempting further development of scant local water supply resources, Los Angeles, with great foresight, adopted the bold expedient of diverting an unused mountain stream 250 miles distant and turning it from its course into the desert to the uses of the city. At a cost of \$24,500,000 it made available indefinitely a municipal supply of 259,000,000 gallons per day in a locality where water is more scarce and more valuable than in any other thickly settled part of this country. In doing this Los Angeles acquired a natural resource of almost inestimable value and has insured its future growth and supremacy in the southwest.

The city of San Francisco has undertaken a similar great municipal water supply project. It is now building works to develop by storage in the Hetch-Hetchy valley, 175 miles distant, a supply of 240,000,000 gallons per day, present maximum capacity. This supply is estimated to cost about \$37,000,000 and may ultimately be developed to furnish 400,000,000 gallons per day. The works will include a great dam on the Tuolumne River and an aqueduct and equalizing reservoirs similar to those of the Catskill and Owens River supplies.

The immense difficulties overcome and the great engineering works carried out in recent years to develop adequate water supplies for some of our great cities have had their counterpart on a smaller scale in the planning and execution of works required for the supply of many of our smaller cities. These cities, even though oftentimes

unfavorably situated for the development of the necessary quantities of water, must on account of more limited means depend on local sources of supply.

Ground water supplies have been very extensively developed during recent years, mainly by the smaller inland cities. Sometimes there has been practically no alternative source, but in other cases this source has been developed to supplement other supplies, or used in preference to a polluted river supply requiring filtration. In the case of the Bay cities of California, ground water supplies have been extensively developed to supplement a scant impounded supply in a region where no rivers for water supply are available, except at a great distance and prohibitive cost. The La Crosse, Wis., supply is a good example of the latest practice in developing ground water supplies from favorable water-bearing sands by means of driven wells. This city recently abandoned a polluted river supply for one that does not need artificial filtration. A modern example of one of the largest ground water supply developments is Des Moines, Iowa, which is able to develop an ample supply by means of infiltration galleries in the sand and gravel deposits of a nearby river.

Deep well supplies in some localities have continued to offer the best available supply in the case of a number of our smaller cities and towns, but the continued and increasing draught on these sources, with attendant lowering of the static water level, has made this supply in many cases less economical of development than when first tapped, and it is now well recognized that this source of supply is not always well adapted to progressive enlargement to meet the growing needs of the town supplied. The deep well supply will continue, however, to be a valuable asset to many of our smaller cities situated in certain well-recognized zones favorable to the development of water from the underlying rock strata.

With the continued growth of our cities and the increasing rate of water consumption, the problem of supplying water will continue to be a vital one for many of our cities, most of which are pressed to keep ahead of the insistent demand for more water. In certain sections of the country the very limited water resources are, without a doubt, a serious handicap to cities already existing. Where the growth of the city is sufficiently sustained, we may expect to see other great water supply projects undertaken, as at New York and Los Angeles, in order to overcome deficiencies or exhaustion of the local water supply resources.

SANITARY QUALITY OF WATER

The most notable recent advance in the art of water supply has been the improvement in methods of water purification. In the face of ever-increasing pollution of our water courses, the quality of water as supplied to the consumer has practically within the last fifteen years been raised to a high standard of purity and safety in most, if not all, of our public water supplies. This result has been secured in part by protecting watersheds from contamination, but is due mainly to the very general introduction of water filtration and water sterilization. Today it is the exceptional water supply that does not provide a safe, clear and practically colorless water. This is the greatest achievement of recent water-works progress.

The importance of the radical improvement brought about in the sanitary quality of our water supplies within the past twenty years, is indicated by the reduction in the typhoid fever death rate. George A. Johnson is authority for the statement that a reduction of 16 deaths per 100,000 population in the 33 cities having over 100,000 population in 1910, that have introduced some form of water purification, may be attributed to water purification. On this basis, in these cities alone, there are annually 2600 fewer typhoid fever deaths than under the old conditions with polluted water, and the saving in typhoid fever cases is estimated at 39,000 per year for these same cities. These conclusions are based on typhoid statistics for the period 1900-1912 by comparing the average rate for 1900 to 1908 with the average for period 1909 to 1912. If we take account of the increase in population using filtered water since 1912 and the population supplied with filtered water in communities of less than 100,000 people, it is evident that the above estimate of 2600 typhoid deaths per year is probably much below the actual total annual saving in this disease alone made by water purification. There is good evidence to show that the death rate from other causes has also been materially reduced by water filtration.

WATER FILTRATION

Stimulated by wide dissemination of modern ideas of sanitation, water filtration in the United States has made great progress during the past decade. The population supplied by filtered water, as

shown by Table 1, has increased from 3,160,000 in 1904 to 17,291,000 in 1914. As late as 1903 only about 60 cities and towns were supplied with filtered water, while there are now some 480 filter plants in this country with a total capacity of 2,585,000,000 gallons per day. These filters serve 40.86 per cent of the urban population, while in 1904 only 9.66 per cent of the urban population (including all towns of over 2500 population) was so supplied.

The relative growth of slow sand and rapid sand filtration during this period is interesting. It reflects strongly the relative adaptability to conditions in this country of the two types of filters and the gradual acceptance by the general public of ideas in water puri-

TABLE 1

Growth in population supplied with filtered water in the United States by slow sand and by rapid sand filters

YEAR	TOTAL URBAN POPULATION IN THE UNITED STATES (TOWNS AND CITIES ABOVE 2500)	POPULATION SUPPLIED WITH FILTERED WATER			PER CENT OF URBAN POPULATION SUPPLIED		
		Slow sand filters	Rapid sand filters	Total	Slow sand filters	Rapid sand filters	Total
1870		None	None	0	0.00	0.00	0.00
1880	13,300,000	30,000	None	30,000	0.23	0.00	0.23
1890	21,400,000	35,000	275,000	310,000	0.16	1.29	1.45
1900	29,500,000	360,000	1,500,000	1,860,000	1.22	5.09	6.31
1904	32,700,000	560,000	2,600,000	3,160,000	1.71	7.95	9.66
1910	38,350,000	3,883,000	6,922,000	10,805,000	10.13	18.05	28.18
1914*	42,500,000	5,398,000	11,893,000	17,291,000	12.70	27.98	40.68

* Compiled January, 1914, by George A. Johnson.

fication looked upon with prejudice less than ten years ago. Although slow sand filters were the first to be introduced, by 1904 rapid sand filters, including the earlier "mechanical" filters, were far in the lead with a total population served of 2,600,000, as against only 560,000 supplied by slow sand filters. From 1904 to 1908 several very large slow sand filter plants were completed, at Philadelphia, Pa., Washington, D. C., and at Pittsburgh, Pa., and the relative lead of rapid sand filters was much reduced, although even then the population served by rapid sand filters was very nearly twice that supplied by slow sand filters. Since 1910 the growth of slow sand filters has been less marked. In 1914, a population of 5,398,000 received water from about thirty slow sand filters, while

upwards of 450 rapid sand filters supplied a total population of 11,893,000.

Although there are now in this country 15 rapid sand filter plants to one slow sand plant, the capacity of the larger slow sand filter plants is greater than that of any rapid sand filters yet built. The largest slow sand filter, located at Philadelphia and in service since 1908, has a rated capacity of 240,000,000 gallons per day. In contrast to this, the rapid sand filter at Cincinnati, completed in 1907, with a capacity of but 112,000,000 gallons per day, is the largest plant of this type in operation up to 1915. Present tendencies in

TABLE 2

*Decline in typhoid fever death rate in eight cities following the use of hypochlorite disinfection of the water supply**

CITY	BEGAN USING HYPOCHLORITE	BEFORE USING HYPOCHLORITE		AFTER USING HYPOCHLORITE		REDUC- TION IN DEATH RATE
		Period	Death rate per 100,000	Period	Death rate per 100,000	
						<i>per cent</i>
Baltimore.....	June, 1911	1900-10	35.2	1912-13	22.8	35.0
Cleveland.....	September, 1911	1900-10	35.5	1912-13	10.0	72.0
Des Moines.....	December, 1910	1905-10	22.7	1911-13	13.4	41.0
Erie.....	March, 1911	1900-10	38.7	1912-13	13.5	65.0
Evanston.....	December, 1911	1907-10	26.0	1912-13	14.5	44.0
Jersey City.....	September, 1911	1900-07	18.7	1909-13	9.3	50.0
Kansas City.....	January, 1911	1900-10	42.5	1911-13	20.0	53.0
Omaha.....	May, 1910	1900-09	22.5	1911-13	11.8	47.0
Poughkeepsie.....	1908	1900-08	54.0	1908-13	18.5	65.8

* Taken in part from paper by C. A. Jennings, "Hypochlorite Treatment Now Firmly Established."

this country are indicated by the fact that several cities are now building mechanical filter plants larger than any now in operation, while no large slow sand filter plants are under construction or projected. A rapid sand filter of 320,000,000 gallons capacity, 30 per cent larger than any existing slow sand plant, has been designed for the Croton water supply of New York. St. Louis has recently completed a rapid sand filter of 160,000,000 gallons capacity; at Cleveland two rapid sand filters are proposed with a combined capacity of 225,000,000 gallons, one of which is now about ready for service, the larger plant of the two having 150,000,000 gallons

capacity; Baltimore has a new rapid sand filter of 128,000,000 gallons capacity.

The rapid sand filter has outstripped the slow sand filter principally because it is better adapted to handle waters of the high turbidity characteristic at times of practically all our rivers outside of the extreme northeasterly portion of the United States. In many parts of the country, the slow sand filter, unaided by auxiliary processes, more especially coagulation and preliminary sedimentation, would be incapable of continuously handling the water except at greatly reduced rates of filtration, owing to the rapid clogging of the beds and great difficulty and time required in cleaning. The rapid sand filter, using coagulation and ample preliminary sedimentation that relieves the filters proper of a very large share of the burden of purification, and with easy means of cleaning the filter beds, has, on the other hand, repeatedly demonstrated its ability to properly and economically filter the most turbid waters. The growing recognition by engineers of the merits of the rapid sand filter is evidenced by the final recommendation in a number of instances of rapid sand filters, reversing earlier recommendation of slow sand filters, as in the case of New York, Baltimore, and Minneapolis.

Although the limitations of slow sand filtration in handling waters of high turbidity were early realized, these filters were often favored in preference to rapid sand filters. Popular objection to rapid sand filtration arose on account of its use of a coagulant. This prejudice is well illustrated in the case of Washington, D. C., where popular agitation resulted in the building in 1905 of a slow sand filter after the original recommendation of a rapid sand filter. Prejudice against the use of alum, and, in fact, against the use of other chemicals, either for coagulating, softening, or sterilizing water, has now been for the most part overcome. This is mainly due to the extensive use of coagulation at a large number of rapid sand filter plants, occasionally in conjunction with water softening, without ill effects on the consumer, and to the well earned public favor enjoyed by the process of water sterilization by means of hypochlorite of calcium.

While the rapid sand filter has overcome the prejudice under which it labored ten or fifteen years ago, and has been demonstrated as equal, if not superior in bacterial efficiency to the best slow sand filters, it is of interest to note that the attempt in recent years to apply slow sand filtration outside of its proper zone of relatively

clear natural waters has not met with success. This attempt has brought about very radical departures from early slow sand filtration practice, and has obscured the original sharp distinction between this type and the rapid sand filter, without evolving a superior filter. It has been necessary to resort to coagulation at the Washington slow sand plant, in spite of very long preliminary sedimentation. At Philadelphia and at Albany, preliminary filters which are practically rapid sand filters, have been added to better enable the slow sand filters to do the work originally expected of them. At Pittsburgh extensive modifications have been necessary to properly prepare the water for the slow sand filters that had been proved incapable alone of producing a satisfactory effluent. The reliance now placed on sterilization of the filtered water at most of the principal slow sand filter plants shows further the wide departure made from the original slow sand process, in the effort to keep the performance of some of these plants up to the standard originally intended of them without the help of these and other auxiliary processes. All of these processes are foreign to the original idea of a "natural" process for water purification, which gave to the slow sand filter much of its vogue and played an important part in meeting the early competition with the so-called "mechanical" filter and the present rapid sand filter.

The process of rapid sand filtration was highly standardized ten years ago, and has undergone little change in the last few years beyond the incorporation of water sterilization as an additional safeguard, and a more general appreciation of the importance of preliminary sedimentation. Filters of this type follow closely the lines of the original modern rapid sand filter built in 1902, at Little Falls, N. J.

Although it is well understood that any filter has a definite limit of capacity beyond which it is not possible to obtain properly purified water, there is a tendency to operate filters at greater than the safe rates, as the plants are outgrown. The danger in this practice is evident, and engineers generally are disposed to discourage it, and, so far as possible, to anticipate it by designing with ample provision for the needs of the immediate future, and with special attention to facility for making future additions.

There is a further tendency of late to overconfidence in filtration as a preventive of disease, and a disposition in some quarters to attempt the filtration of badly polluted waters in preference to more

expensive and distant sources. The engineer and the sanitation expert of today is engaged in pointing out that it is not a proper or wise policy to overload water filters from a poor source of supply.

The field of possible application of water filtration, and more particularly rapid sand filtration, is today a very broad one. Practically all river and large lake municipal water supplies, and many impounded supplies, must eventually be filtered to meet the rapidly spreading demand for uniformly safe and potable water. We may reasonably look forward to an extension of water filtration during the next decade fully as great as the growth from 1904 to 1914.

WATER DISINFECTION

The calcium hypochlorite process of water sterilization is the most important single contribution to the art of water purification in recent years. This process, introduced in 1908 at the Boonton reservoir of the Jersey City Water Supply Company, spread very rapidly to the great benefit of our public supplies. Many cities which were not ready to undertake water filtration applied the bleaching powder process of sterilizing the water as an emergency measure. Many water-borne typhoid epidemics were controlled by this means and some very remarkable results were secured in the reduction of the typhoid death rate.

A radical improvement in water sterilization methods was made with the introduction in 1910 of liquid chlorine, and this process has practically supplanted the older one and, through overcoming some of the objections to the hypochlorite process, has further extended the field of water sterilization and has been of great value in improving the sanitary quality of many public water supplies.

Although water sterilization deserves every praise, continued experience leads to the conclusion that this process should not displace filtration in waters containing more or less suspended matter. It cannot make a dirty water clean or wholesome. While it has been very successful as an emergency measure, even on waters to which it is not best adapted for continual use, it should not be regarded as a proper permanent remedy for a badly polluted supply or one in which the water is periodically of high turbidity. The tendency of the best water-works practice is to adopt filtration with sterilization as an added safeguard in such cases.

The very remarkable development of hypochlorite disinfection in

this country and the more recent introduction of liquid chlorine have put water purification on a sound basis. We are safe in concluding that disinfection has come to stay, even though the disinfecting agent may be changed in the future by the further improvement of processes now known or the discovery of new and better methods.

The ozone and violet ray processes of water sterilization have been exploited to a very limited extent in this country. They have not as yet found application on a commercial scale in any of our important public water supplies, and it does not appear likely that they will soon displace the liquid chlorine process, if at all.

EVOLUTION OF PUMPING MACHINERY

The apparently secure place occupied a few years ago by the cross-compound, high-duty reciprocating pump is today challenged by the turbo-centrifugal pump.

Until very recently the vertical, triple-expansion, reciprocating pumping engine was preeminent for high service pumping under continuous operation where capacities ranging from 10,000,000 to 30,000,000 gallons per day were required. This type of engine was highly developed over a decade ago and has undergone comparatively little further improvement in the last ten years. It seems that the limit of its performance has practically been reached at 185,000,000 foot pounds per 1000 pounds of dry saturated steam. The use of superheated steam has raised the attainable duty limit to slightly above 200,000,000 foot pounds per 1000 pounds steam, although the duties are not comparable on this basis. The introduction of superheated steam has not become general, even in the larger plants, though it represents the principal recent advance made in improving the performance of this type of pump.

Also, until recently, for the smaller capacities required in high service units ranging from 2,000,000 to 10,000,000 gallons per day, the horizontal, cross-compound, crank-and-flywheel condensing pumping engine has had a practically undisputed field in water-works service. These machines have a duty range of from 110,000,000 to 145,000,000 foot-pounds per 1000 pounds dry steam and have very generally superseded the direct-acting, non-rotative pumping engines formerly used. This type, like the triple-expansion pumping engine, was so far perfected ten years or more ago that but

TABLE 3
Duty performances of vertical triple expansion pumping engines

BUILDER OR DESIGNER	DATE OF TEST	LOCATION OF ENGINE	CAPACITY PER 24 HOURS	PISTON SPEED		HEAD		INDICATED HORSE POWER	MECHANICAL EFFICIENCY	STEAM I. H. P. HOUR	B. T. U. I. H. P. MINUTE	DUTY IN FOOT POUNDS PER 1,000,000 B. T. U.	DUTY IN FOOT POUNDS PER 1,000 POUNDS STEAM	THERMAL EFFICIENCY
				feet	feet	feet	pounds							per cent
1. Edw. P. Allis Co.	1900	St. Louis, Mo., No. 10.	15,000,000	197.00	292.00	126.0	126.00	802.00	96.8	10.680	202.0	158,077,320	179,454,250	21.00
2. Edw. P. Allis Co.	1900	Boston, Mass. (Chestnut Hill)	30,000,000	195.00	140.00	61.0	185.00	748.00	93.3	10.330	196.0	163,925,300	178,497,000	21.63
3. Edw. P. Allis Co.	1903	St. Louis, Mo., No. 12	15,000,000	197.00	293.00	126.8	135.00	796.00	97.7	10.880	205.2	156,900,000	177,200,000	20.67
4. Allis-Chalmers	1906	Milford, N. J.	12,000,000	203.60	334.75	145.2	176.67						181,433,826	
5. Holly	1909	Albany, N. Y.	12,000,000	221.40	322.21	139.8	153.56						182,281,000	
6. Allis-Chalmers	1909	Nashville, Tenn.	20,000,000	239.04	385.00	167.0							184,700,000	
7. Allis-Chalmers	1910	Milwaukee, Wis.	12,000,000	204.20	279.00	121.0		618.00	97.1	10.820	209.0	151,000,000	175,400,000	20.25
8. Holly	1910	Philadelphia, Pa.	20,000,000	221.43	220.85	95.9	180.19					163,330,000	184,476,000	
9. Camden Iron Works	1908	Cincinnati, Ohio	30,000,000	248.00	140.00	61.0	151.40	811.00	93.1	10.720		154,600,000	171,700,000	19.86
10. Camden Iron Works	1908	Cincinnati, Ohio	30,000,000	248.00	140.00	61.0	148.90	806.30	93.90	9.550		163,000,000	194,403,500*	21.99
11. Bethlehem Steel Co.	1914	Pittsburgh, Pa. (Mission St. Sta.)	7,000,000	200.69	441.08	191.5	160.40	574.83	97.63	9.597			201,662,445†	

* 163° superheat.

† 100° superheat.

slight improvement has since been made in its efficiency. Both the vertical compound and the horizontal direct-acting, non-rotative, triple-expansion pumping engines are still in the field, but less generally used in water-works service than the cross-compound pumping engine and the vertical triple.

Great strides have been made in the last two or three years in improving the efficiency of the turbo-centrifugal pump, which until recently was useful in water-works service mainly for low lifts or as reserve machinery for peak load and fire service. The efficiencies now attainable with this type of machinery greatly extend its field of usefulness in water-works practice and promise to make the various types of reciprocating pumps obsolete in the near future. Centrifugal units are now being built with duty guarantees equal to those of high-duty, cross-compound pumping engines operating under the same conditions. On the basis of equal duties the advantage of first cost and compactness is in favor of the centrifugal pump.

Although the record duty so far obtained with centrifugal pumps in water-works service, 164,000,000 foot-pounds per 1000 pounds dry steam, is still considerably below the best vertical triple-expansion pumping engine duty records, the smaller first cost of the turbo-centrifugal unit gives it the advantage over the older type of machinery. There is little question but that the present tendency is toward a very considerable invasion of the water-works pumping field by the latest types of high-duty centrifugal pumps.

Gas-driven pumps have had only rather limited application to municipal water-works service in this country, and there does not appear to be any marked tendency to increase the use of this type of machinery on a large scale.

Interesting developments have been made since 1900 in means for the withdrawal of water from tubular wells, not only for ground water but for deep well supplies. Following the first notable installation of tubular well centrifugals at Petrograd, Russia, in 1900, self-balancing centrifugals of small diameter in multiple were successfully made and tested at the Clearing Yards in Chicago in 1902, with efficiencies of about 50 per cent. Installations at La Grange, Ill., Waterloo, Iowa, and Milwaukee followed, and this type of pump, while not having a wide field to fill, has proved itself useful where needed. A recent installation at Rockford, Ill., includes not only tubular deep-well centrifugals in multiple, but is augmented

by series centrifugals at the surface of the ground, delivering the well water under city pressure directly into the city distribution system. Notable experience with tubular well centrifugals has been had in a number of suburbs of Chicago, at Memphis, Tenn., Winnipeg, Canada, and elsewhere.

THE DISTRIBUTION SYSTEM

In keeping pace with our rapidly expanding cities, water-works distribution systems have been in the aggregate greatly extended during the past decade. Largely as a result of the influence of this Association, standardization of cast-iron water pipes has been brought about. Valuable experience has been gained in the comparative advantages of various materials for water pipe under widely varying conditions. The problem of electrolysis has received much attention, and has led to the application of corrective measures. The important part played by the distribution system in continuity of service has been demonstrated in several noteworthy and regrettable instances. Breakages of mains from defective pipe, by water hammer, by settlement and displacement of pipes from nearby construction, and by flood, fire and earthquake, have all been the cause of serious interruption of service and in some cases disaster.

The losses, sustained as a result of these breaks, through interference with industry, suspension of fire protection, and pollution of the water supply, have been in some instances very great. Some of the worst conflagrations of the past decade followed water pipe breaks that resulted in failure of fire protection at a critical time. The importance of avoiding such losses and increasing the factor of safety in water distribution has led, in some cases, to the provision of cisterns scattered through the distribution system where there is danger of disruption of the system from any cause. The need of having duplicate supply mains or conduits and the importance of provision for promptly isolating parts of the distribution system, by valves always accessible and quickly found, and other precautions, is perhaps much better recognized today than formerly.

No notable changes in the material of distribution pipe and accessories has taken place of recent years. But much more attention is being given to clean interior surfaces, and means for this kind of maintenance are better known and utilized. Of special interest has been the ingenious development of making large con-

nections and inserting valves, without shutting off the flow of water. Cast-iron pipe of 16-foot-lengths are now manufactured and are available, and the joint for cast-iron pipe has received much attention, without so far seriously displacing the standard practice of using lead.

WATER CONSUMPTION

With several of our largest cities still lavish in the waste of water, it is plain much remains to be done in bringing about economy in the use of water and the elimination of waste. The per capita consumption of water in this country varies from less than 40 gallons per day in some cities to 400 gallons per day in others. This wide range in rate of consumption is still more striking if we compare it with the prevailing rates in Great Britain, where the combined domestic and trade consumption is in several cities even below 25 gallons and the highest rate reported only 70 gallons per capita. Even allowing for a somewhat more liberal legitimate domestic use of water in this country, it is difficult to reconcile the high rates so common in this country with the low per capita consumption abroad, and the lower rates of consumption in some of our own cities. The explanation is to be found mainly in leakage and lavish and careless use and waste on the part of the consumer. This has been demonstrated repeatedly in recent years by thorough investigations, by successful campaigns to reduce waste, by water waste surveys and by wide experience with metering.

New York City, threatened by water famine before the completion of the Catskill supply, was able in 1912 by systematic surveys and a waste prevention campaign to reduce the total water consumption 90,000,000 gallons per day below the estimated needs for that year. Washington, D. C., and other cities have carried on work of this kind on a more or less extensive scale and with beneficial results. Waste surveys in Chicago not long ago revealed an astonishing amount of leakage and led to the detection of entirely unsuspected sources of waste.

Ingenious devices have been developed for measuring and checking the flow of water in distribution mains.

METERING

Unintelligent opposition still stands in the way of metering in such important cities as Chicago and Buffalo and in many smaller

cities, where the present apparent per capita water consumption is altogether unreasonable. The presence of an abundant visible source of supply, as at Chicago, without doubt militates against considerations of economy and strengthens the popular notion that water should be "free as air."

These cities may be expected in the not distant future to fall into line by adopting an effective policy of metering. The possibilities of economy of water in these cities, now using in some cases as high as 400 gallons per capita per day, are best indicated by the prevailing low rates of consumption in those cities that have adopted

TABLE 4

*Comparison of percentage of metered services at different periods in eighty-two large American cities**

PRESENT SERVICES METERED per cent	1900		1906-12†	
	Number of cities	Total population	Number of cities	Total population
100	1	32,700	7	660,300
75-100	13	848,700	21	2,818,900
50- 75	5	509,300	12	1,004,000
25- 50	15	1,221,200	14	1,718,600
10- 25	9	636,300	10	2,047,100
0- 10	39	11,513,500‡	18	11,569,300§
Total and averages.....	82	14,761,700	82	19,872,200

* These cities were all over 25,000 population in 1900.

† The data in this column were obtained for various years from 1906 to 1912, inclusive, most of them being for the years 1910, 1911 or 1912.

‡ Includes New York and one other city reported as having no meters.

§ Includes New York and six other cities reported as having no meters.

metering, including Cleveland, Milwaukee, Hartford, Des Moines and many others. The striking results in economy where metering has been applied to a wasteful system is sufficient argument for the general adoption of this policy wherever apparent consumption of water is beyond all reasonable use. The few examples, of which York, Pa., is a striking instance, of moderate water consumption although practically unmetered, are exceptions rather than an argument for unmetered services.

The great loss of continued and unnecessary increased water supply development, especially under present abnormal prices,

makes it doubly important for all of our cities to keep water consumption within bounds. Threatened outgrowth of supplies already developed and the growing need for the greatest possible economy in plant operation may be expected to greatly accelerate the adoption of metering in those cities that have not yet taken advantage of the meter system, which offers at once the only fair method of selling water and the best insurance of economy in use of water.

VALUATION AND RATES

During the decade just passed, there has been a notable movement for state and national regulation of public utilities where water supplies have been privately owned, and in some states, where they are municipally owned. This regulation has operated to control more thorough examination of the value of the property devoted to the public use, the proper return to be afforded it, and the just and equitable apportionment of the income to be raised among the different classes of consumers. Nearly all of the states now have established public utility commissions having more or less power to regulate rates, require uniform accounting, and value property devoted to the public use. A very few of these commissions, with restricted powers, existed prior to 1907, but the great majority of them, and notably their enlarged powers, have been created since about that date. Inasmuch as these commissions are largely new to their responsibilities and the subject of rate regulation, both in the economic, financial, and legal questions raised, is admittedly difficult and complicated, their proceedings are watched with interest, and the subject is now being extensively studied.

During the past decade the transfer of water supply utilities to municipal ownership has continued, though less rapidly than in prior years as the number of privately owned plants diminishes. Approximately \$15,000,000 in value of private utility property in water supply has become municipally owned since 1905 in the United States, and several large properties yet remaining in private hands will undoubtedly be transferred to the public control at an early day.

CONCLUSION

Any attempt to cover the notable matters in which municipal water supply has progressed in this country during the last decade

must necessarily be treated broadly. Many interesting developments of a minor character must necessarily be omitted, but it is believed that the more important developments have been described.

For the future it is apparent that more attention is to be given to the conservation of our available supplies and their protection from contamination. This movement is already well begun in the studies of the Great Lakes, the sanitary survey of the Ohio River, and the valuable and earnest work of the state water surveys now in progress in many states over the country. More and more will this close watchfulness over the purity of our water-courses and water reserve prevail, if present indications are any guide.

Another tendency in the near future will undoubtedly relate to the increased curtailment of waste. This movement, already well in progress, will have yet wider attention the more its economic necessity becomes apparent and the increasing difficulty of extending present supplies compels the attention of our municipalities.

New and revolutionary discoveries are always possible in any art, but without discussing these opportunities for betterment it is easily to be seen that we have yet a great deal to do to organize, systematize, and standardize the problem of public water supply in this country in the next few years.

DISCUSSION

RUDOLPH HERING: The author has prepared the best short compilation of known facts on this subject that the speaker has seen anywhere. He has not only touched upon all of the chief elements that must be considered in water supplies, but he has brought out the present views of those who have been engaged in water supply development. He said that the consumption in Europe is very much less than here, because the people there are in general more economical. The traveler in Europe is constantly surprised to see how saving they are with water. The speaker had the pleasure of visiting several American cities with J. D. Watson, one of the leading English engineers, and observed that he could not suppress his continual astonishment at what he termed the inexcusable waste of water in American hotels and homes. The waste is really a question of habit and custom and unless Americans radically change their custom we will have to provide for a constantly increasing consumption.

There is perhaps one thing that might be added to the points raised in the paper. It has not been regarded in the United States as much as in Europe as an important matter, where it has been held so important that it has in several cases decided the selection of the source of water supply. This is water temperature. Berlin, Vienna, Hamburg, Paris, and most large European cities are largely, if not wholly, supplied with ground water. Their people say, "We wish low temperature, we wish to have the water delivered in our houses like spring water, clear and cold." Therefore, ground waters have been developed because it is practicable to preserve their low temperatures. It is quite practicable and safe to introduce them also in the United States more than has been done, particularly along the Pacific Coast and in the northern sections. There is a great future for that class of supply in this country. Most ground waters do not need filtration and when kept in covered reservoirs are cooler. In Europe the consumption of ice in summer is very low as compared with that here, mainly due to the fact that they have cool water when drawn from the spigot in almost every city.

FRANCIS F. LONGLEY: The speaker was interested in the remarks on the author and likewise of Dr. Hering as to the smaller waste in European cities as compared with that here. The statement is frequently made in this country that in order to meet American conditions it is impossible to have a distribution system that will account for 100 per cent of the supply furnished to the city. The office with which the speaker is associated recently had occasion to study this question at some length, and in the course of the study to refer to European statistics bearing on waste in water consumption. The statistics referred to covered some four hundred cities, mainly in Germany. Out of these 400 cities there were reported for the year 1912, 11 cities in which 100 per cent of the water furnished was accounted for, 36 in which at least 95 per cent was accounted for, and nearly half of the entire list accounted for 75 per cent or more of the supply. The best records of American cities do not approach these figures. The speaker does not know of any record as high as 95 per cent. Records of 85 per cent are infrequent and the percentage of cities accounting for 75 per cent or more is certainly not large.

In these European cities, of course, water mains and fixtures are not provided on the same generous basis as here in the United

States. Here there is a tendency to provide facilities for the use of water whenever it will be even remotely convenient. There the tendency is to provide fixtures only where necessary. The number of fixtures per unit population is much smaller than here. The per capita consumption there is nearly everywhere lower. The use of meters on every service is much more general. A more definite control is exercised over waste of water. These factors all contribute to a smaller amount of waste or a larger percentage of the total supply accounted for. Nevertheless, this comparison has an important significance, and most American cities may well take a lesson in thrift in this phase of the water supply problem from these European cities.

JAMES W. ARMSTRONG: The author has called attention to the increasing use of centrifugal pumps for water works purposes, and compared the efficiency and first cost of high duty, reciprocating pumping engines, with centrifugal pumps, but he said nothing regarding the comparative cost of the operating force necessary to run them. Very little attention seems to have been given to this item of expense, yet it is one of the most important entering into the consideration of a given problem. While local conditions have much to do with the number of men employed in any plant, and comparisons of isolated cases are liable to be misleading, there should still be a value in all reliable figures comparing the labor costs of the two types of plants.

The writer has access to the labor costs of operating three different pumping stations in the city of Baltimore, and submits a comparison hoping that additional information of a similar kind may be published.

By comparison it will be seen that the Mt. Royal Pumping Station has an annual cost per million gallons of capacity 7.3 times greater than that of the Montebello plant. The cost of the boiler room labor has not been taken into consideration, as the Montebello plant is electrically driven and no such cost exists.

The larger a centrifugal pumping plant is, the smaller will be its annual cost per million gallons of capacity. For instance, the Montebello plant could have its capacity increased to 240,000,000 gallons without requiring any additional force for operating, and its annual cost per million gallons would be then reduced to \$18.12.

On the other hand, the writer knows a small water works centri-

The Mount Royal pumping station—water

Total pumping capacity, 65,000,000 gallons per day; head pumped against 242 feet. Installation, one 30,000,000-gallon vertical triple-expansion engine (new), 180,000,000-foot pounds duty; two 17,500,000-gallon horizontal, duplex, triple-expansion engines (old), about 115,000,000 foot-pounds duty.

NUM- BER OF MEN	POSITION	ANNUAL SALARY	ENGINE ROOM COST	BOILER ROOM COST
1	Engineer in charge.....	\$1,300	\$ 1,300	
2	Watch engineers.....	1,200	2,400	
1	Assistant engineer.....	1,080	1,080	
1	Auxiliary engineer.....	10,20	1,020	
3	Oilers.....	720	2,160	
3	Firemen.....	780		\$2,340
1	Mechanic at \$3.50 per day; average 300 days; half time to engine room.....		525	525
19	Laborers at \$2.25 per day; average 300 days; 35 per cent engine room and 65 per cent boiler room.....		4,489	8,336
			\$12,974	\$11,201

Annual cost of engine room, per million gallons capacity, \$199.60.

Main sewage pumping station

Total pumping capacity, 72,500,000 gallons per day; head pumped against, 72 feet. Installation, three 27,500,000-gallon, vertical triple expansion pumping engines, 165,000,000 foot-pounds duty.

NUM- BER OF MEN	POSITION	ANNUAL SALARY	PUMP ROOM COST	ENGINE ROOM COST
1	Engineer in charge.....	\$1,500	\$1,500	
4	Shift engineers.....	1,140	4,560	
3	Assistant engineers.....	1,020	3,060	
3	Oilers.....	720	2,160	
4	Firemen.....	780		\$3,120
1	Mechanic.....	1,020	510	510
1	Helper.....	960	480	480
1	Storekeeper.....	1,020	510	510
8	Laborers at \$2.25 per day; average, 300 days; half time to engine room.....	5,400	2,700	2,700
			\$15,480	\$7,320

Annual cost of engine room per million gallons of capacity, \$213.51.

Main pumping station, Montebello filters

Total capacity, 160,000,000 gallons per day; head pumped against, 39 feet. Installation, four electrically-driven centrifugal pumps, one of 30,000,000 gallons, two of 40,000,000 gallons and one of 50,000,000 gallons capacity.

NUMBER OF MEN	POSITION	ANNUAL SALARY	PUMP ROOM CHARGE
3	Operating engineers.....	\$1,200	\$3,600
1	Mechanic for relief duty and repairs, half time..	1,500	750
			\$4,250

Annual cost of pump room per million gallons of capacity, \$27.19.

fugal plant located in an isolated position where men are kept on duty more for possible emergencies than for actual operating requirements, where the annual labor cost per million gallons of plant capacity is over \$400. Contrasted with this, and in another city, is a group of small sewage pumping stations, operated automatically by float switches. These stations have been run satisfactorily for a number of years without any regular operator. The only attention they receive is a daily examination from an inspector. The widely different labor costs as shown by the above examples would indicate the desirability of looking carefully into such cost when studying the possibilities of a new installation.